ASSESSMENT OF PASSENGER FORECASTING MODELS

A Report for

the Quebec/Ontario High Speed Rail Study

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1. INTRODUCTION

The estimation of intercity travel demand under conditions where a new travel mode is introduced has always been a challenging task, and continues to require a mix of both science and art.

In studies such as the Quebec/Ontario High Speed Rail Study, the exercise of demand estimation becomes the central focus of the feasibility analysis, and for this reason, parallel demand forecasting is sometimes undertaken. In the Quebec/Ontario study three different consultants have been engaged to provide separate high speed rail ridership and revenue estimates for identical scenarios, allowing as well for individual data collection to attempt to meet the specific requirements of each model structure. This permits the assessment of the implications of alternative model structures on demand estimation, and thereby allows for a much richer base for the understanding of demand behaviour.

While this multiple approach to ridership estimation enriches the feasibility study, it does require that a single set of results be selected for detailed application within the study. This is necessary in order to ensure consistency, since each alternative model has its own internal theoretical base and structure. While it is theoretically possible to conduct expected value analysis to merge the results, from a practical perspective, it makes little sense to merely average the separate forecasts. On the other hand, the availability of the alternative forecasts does allow for improved interpretation and the development of the most significant ranges for sensitivity testing.

It is the specific purpose of this report, then, to assess the relative strengths and weaknesses of the three forecasting models, and to recommend the choice of model results to be used for the final stages of the study.

The assessment of the relative strengths and weaknesses of the models will be conducted in two primary steps:

1. the review of model structures and methods of calibration, and

2. the comparison of model test runs, conducted under common input assumptions.

The results of these two types of assessment are presented in sections 2 and 3 respectively.

2. MODEL REVIEW

The review of the three modelling procedures is based on the assessment of technical documents provided by each of the three consultants, plus an extensive set of 1-2 day meetings of the review panel with each of the consultant teams. All of the consultants were cooperative and direct in their discussions, and the responsibility of interpretation rests solely with the review panel.

For ease of presentation the review panel divided the model procedures per se into two major segments. The first relates to the consideration of the theory and structure of the models, on the basis of four components: total demand, mode choice, induced demand and other procedures (access/egress, yield management). The second segment considered the procedures for the calibration of each of the four components. This has to do with both how and what data were utilized within the model, to best fit the model structure to the 1992 base condition.

2.1 Model Theory and Structure

The information obtained by the review panel in regard to each of the model packages from the three consultants is summarized in Table 1. The common structure applied within the table permits a relatively easy assessment of the primary differences between the alternative model packages. The table serves as the basis for the review of model features, and the four primary model components are applied as a structure for presentation in the following sections.

Total Demand

The estimation of total intercity travel demand is the first step of a three-step procedure necessary to forecast HSR demand. Typically, the approach to total demand estimation involves two components: the prediction of total travel demand without HSR and the prediction of total travel demand with HSR. The former is usually determined by simple time-series analysis, and is necessary for the establishment of a base for determining diverted and induced traffic on HSR. The latter is often accomplished by calibrating a cross-sectional direct demand model, where

total demand = f (socio-economic characteristics, total travel cost by all modes (including HSR)).

As noted in Table 1, CRA's procedure for estimating total demand without HSR was different from the other two consultants, who utilized the results of the time series analyses offered by CIGGT. The expert panel utilized by CRA produced auto growth rates, in particular, which were lower than those interpreted by the CIGGT study. The development of a common base from which to determine HSR impact is obviously important, so CRA was ultimately required to accept and apply the common time series analyses to their forecasts.

In regard to the projection of total demand with the inclusion of HSR, the procedures applied by the three consultants are quite different. CRA does not require an independent estimate of total demand with HSR, as the HSR demand diversion and induced volumes are "built up" from total demand volumes without HSR. Both TEMS and SOFRERAIL apply a cross-sectional direct demand model as defined earlier, by trip purpose and city pair. While these two models are similar in form, the TEMS model conforms more to the expected functional formulation.

Mode Choice

Without doubt, the most critical element of the three-stage demand estimation procedure is that related to mode choice. The approach taken by each of the three consultants is substantially different in nature, and each technique will be defined in turn, before offering comments on the value of each.

The SOFRERAIL mode choice model is multinominal in structure, but uses relative modal utilities rather than the more conventional logic formulation. This may have been done to try to avoid the independence from irrelevant alternatives (IIA) property of the multinominal logic model, where travellers using HSR are estimated to be drawn from competing modes in proportion to the mode share of trips on existing modes. However, the chosen model structure still suffers from the IIA problem. In addition, the probability distribution function becomes linear in form, which is a very simplistic assumption for mode choice behaviour.

The SOFRERAIL mode choice model does make use of a unique generalized cost function, which incorporates the difference between actual and desired departure times rather than just departure frequency. The domain of mode choice is also highly disaggregated by time of day, so that in fact, there may be as many as 323 options within the day (20 air departures, 5 train departures, 10 bus departures, and 288 automobile departures).

TABLE 1 - SUMMARY OF MODEL CHARACTERISTICS

Model Components	Model Package		
	CRA	TEMS	SOFRERAIL
Overall model structure	1. demand projection by mode and city pair without HSR 2. demand diversion to HSR from each competing mode 3. induced demand for HSR	1. total demand projection by city pair, with HSR 2. pairwise modal split at successive levels of choice 3. induced demand for HSR, within total demand model	1. total demand projection by city pair, with HSR 2. simultaneous mode choice 3. induced demand for HSR, within total demand model
Market segmentation	10 market segments - 2 trip purposes . business . non-business - 5 primary modes + sub-modes . auto non-captive destination captive route captive . local air . connect air . rail conventional HSR . bus	12 market segments - 3 trip purposes . business . commuter . other - 4 modes . auto . air . rail . bus	192 market segments - 2 trip purposes . business . non-business - 4 modes (calibration) 5 modes (forecasting) . auto . air . conventional rail . HSR . bus - 24 time periods/day
Total demand model	development of average growth rates by mode through expert panel	cross-sectional direct demand model by trip purpose and city pair	cross-sectional direct demand model by trip purpose and city pair, supplemented by time series analysis for existing modes (CIGGT)
Mode choice model	pairwise binary logic (10 models)	hierarchical binary logic (9 models)	relative mode utility model by zone pair (64 models)

Model Components	Model Package		
	CRA	TEMS	SOFRERAIL
Induced demand model	Function of log sum term, calibrated on past experience	Function of change in travel utility relative to existing service and demand elasticity (part of total demand model)	Function of change in travel utility (cost and time), using elasticity of demand as calibrated for total demand model for base condition
Data Utilization	Stated preference data, applied through ordered binary logic process (VPA)	Revealed preference data, and independent application of stated preference data	Revealed preference data (using perceived service variables for existing modes)
Access model	Average super-zone values (based on TEMS values)	Detailed intra-zonal network representation and assignment	Average zonal values (perceived by user)
Yield Management	Optimization based on 4 major route segments and 2 trip purposes	Optimization based on 3 major route segments and 2 trip purposes	Optimization by city pair and trip purpose for 12 time periods per day
Other Features	Assessment of 2 air sub-modes & of 3 auto sub-modes by degree of captivity	Application of 1987 data to compare recessionary (1992)/non recessionary models	Application of service frequency variation by time of day, and use of desired time of departure

The mode choice approach applied by TEMS involves a hierarchical binary logic structure (for 3 trip purposes and 3 levels of binary choice), thereby taking advantage of the non-linear, logic formulation but minimizing the problem associated with the IIA property. The challenge lies in the choice of the hierarchial structure of the model. While the first step in the hierarchy involves the choice between the automobile and public modes, it is not obvious whether the next choice is between ground and air modes, or between high-quality and low-quality public modes.

For theoretical consistency, it is necessary that the hierarchial binary choice model apply inclusive prices or log sum terms for combining the level of service characteristics for public modes, or for combined modes at any level in the hierarchy. This requires the assumption, however, that trade-offs between time and cost components are considered in a similar way at each level.

The third approach to mode choice estimation is that offered by CRA who apply a pairwise binary logic model to the estimation of the share of trips diverted from each existing mode to the new HSR mode. The advantage of this approach is that it allows for differential behaviour by travellers on existing modes, in response to the characteristics associated with the new HSR mode and totally avoids the IIA problem. Conceptually, this permits different functional forms and coefficients for the binary choice between each existing mode and HSR.

Induced Demand

Induced travel demand may be defined as trips which currently do not take place in the system, but occur in the future in direct response to the improved level of service provided by the new mode. It is important that the methodology for predicting induced travel be consistent with the methodology for estimating mode choice, since it is expected that traveller reactions to improved level of service variables should be similar.

All three consultants would appear to be internally consistent in their own definition of induced demand, although the formulations are different in each case. SOFRERAIL utilizes a value of demand elasticity with respect to travel utility, as estimated from the total direct demand equation. The utility value, however, is based on a truncated version of the generalized cost, without departure frequency and the mode constant.

The TEMS methodology for induced demand estimation also makes use of demand elasticity, but presumably does so based on the utility functions as calibrated within the mode choice model.

Finally, the CRA induced demand formulation incorporates log sum terms for the high-speed common carriers (air and HSR) with an elasticity value calibrated from past studies.

Other Models

A number of other model components complement the three primary elements of demand estimation. Of particular interest are the access/egress estimation procedures and the methodology for yield maximization. In the case of the access/egress model, TEMS distinguish themselves by developing a detailed intra-zonal network for access and egress to and from major modal terminals. This permits them to test alternative HSR station locations and to estimate demand for a much finer O-D matrix. Both CRA and SOFRERAIL utilize average access/egress times by mode for superzones.

In regard to yield management, it is SOFRERAIL which develops optimal fares at a very disaggregate level, optimizing on a city pair, trip purpose and time-of-day basis. CRA and TEMS optimize fares by trip purpose for 3 to 4 major route segments in the corridor, and then apply these values throughout the corridor to calculate total revenues.

2.2 Model Calibration

With an understanding of the model structure that is applied by each of the three forecasters, it is now possible to consider how the individual models have been calibrated, to best fit the existing base condition. This section reviews the general calibration procedures followed by each consultant, while the specific model parameters will be presented in part 3 of the report.

For the total demand models, the approaches taken by each of the consultants are totally different. As noted, CRA only requires an estimate of total demand by mode, without HSR in place. While this is normally where they would apply the revealed preference data to a time-series direct demand model, here they have chosen to rely on an expert panel process. This produces an approximate projection only, with no analytical basis. The argument here is that important structural changes are taking place and that these are difficult or impossible to take into consideration.

The most detailed approach to total travel estimation is that developed by TEMS, who calibrate a direct demand model using a series of socio-economic variables. SOFRERAIL has also applied a similar process, but uses only population as an independent variable, within a more simplified functional form. As well, SOFRERAIL fitted a time-series model to the projection of total demand by mode (without HSR), in direct contrast to the CRA approach to the same issue.

For the mode choice models, calibration procedures were equally divergent by consultant. In keeping with the nature of their model, the CRA group uses stated preference data only to fit the mode choice function. Since travellers are responding to the introduction of a new mode, as yet unexperienced, their behaviour can only be interpreted from a survey which seeks to determine responses to the new situation. Much is dependent then, upon the validity of the survey structure and its interpretation. CRA has applied a proprietary ordered binary logic procedure (VPA) to the interpretation of the stated preference survey, but experienced some trouble in mode choice model calibration, due to some undersampling in selected market segments. This necessitated a more general process of calibration and an interpretation in conjunction with other experience.

The TEMS calibration procedure for the mode choice model, on the other hand, made use of both stated preference and revealed preference information, but in an independent manner. Essentially, stated preference data was used to estimate values of time and frequency, which were then applied along with the revealed preference data in the mode choice model. This, of course, raises major issues of consistency in the two sources.

The calibration of the hierarchial binary logic model is not an easy task, since the structure of choices within the hierarchy may be altered as well. This can be assessed, however, by the coefficient value for the inclusive value or logsum term within the mode utility functions. Consistency within the structure is ensured when the coefficient is less than one, and when the coefficients decrease as one proceeds from one choice level to the next highest. This implies the need for manual interpretation and modification within the calibration process.

The TEMS forecasting team has also developed their total set of models for all city pairs in the corridor, as defined by the 1992 situation, rather than the 24 O-D pairs estimated by CRA and SOFRERAIL. This more limited market definition was specified by the study management. The additional city pairs constitute approximately 26% of the intercity rail market in 1992, and therefore the base for forecasting by TEMS is substantially larger than for the other two consultants. It should be said as well, however, that CRA does use the (stated preference) information for all O-D pairs in its calibration exercise, while SOFREFAIL only uses a selected subject (approximately 47 %) of the (revealed preference) data for calibration.

It is worth noting as well that TEMS has also reviewed the 1987 travel demand data, to compare values of time and frequency in a "non-recessionary" period with those in a more recessionary period (1992). This provides a valuable assessment of the relative stability of behavioral parameters over time.

The mode choice model calibration by the SOFRERAIL team differs most dramatically because of its disaggregation by O-D pair, i.e.: the model is calibrated for two trip purposes and 32 city pairs (64 equations). Two other characteristics should also be noted. First, SOFRERAIL has started with a reduced total travel market (47.5 million trips out of 101 million trips in 1992), by eliminating intra-urban trips, connect trips outside the corridor, and captive auto trips. Second, they have used revealed preference data only, so that mode constant terms for the new HSR mode must be chosen as a minimum value from the other mode constants. This represents a major difference from conventional practice and from the other two consultants. Even more, mode service variables as perceived by the survey respondent are used in calibration, rather than actual values. While this is logical from a behavioral perspective, it makes forecasting more difficult.

The most unique feature of the SOFRERAIL mode choice model is undoubtedly the disaggregation by city pair. The calibration results indicate that the coefficients of the generalized cost equation are indeed different, most especially in regard to value of time for business travel, value of frequency for business travel and several of the mode constants for both trip purposes. Interpretation is very difficult, however, since these variations are a function of the particular mix of travellers on each city pair. A more reasonable approach would be to incorporate additional variables (such as linguistic pairing), or to develop separate models for each province.

Next, the induced demand model has its own particular difficulties in regard to calibration. Essentially, it is necessary to determine how many non-travellers in the base period will respond to the increase in level of service as provided by HSR. It is generally assumed that the response will be related to the sensitivity of existing travellers to change in level of service. CRA utilizes an elasticity value obtained from experience in other studies; TEMS and SOFRERAIL apply elasticities as obtained from the calibration of the total demand equation.

Finally, in terms of the "other" model categories, calibration is not a significant requirement. Access/egress times are calculated from the network by TEMS, for use within the mode choice model. SOFRERAIL, on the other hand, utilizes perceived access/egress times and costs from the revealed preference survey.

In summary, it is apparent that each of the three consultants has made use of the available information in its own way, to best fit the requirements of the chosen model structure. It is the suitability of this combination of data and structure which determines the quality of the forecasts.

2.3 Conclusions on Model Structure

As might be expected, the task of summarizing the strengths and weaknesses of the three sets of model procedures is exceedingly complex. In some cases, selected components of the multi-stage estimation process are strong, while others are not, or the associated data may be less than appropriate. The following comments summarize the understanding of the review panel, at this first stage of assessment.

The CRA demand model sequence contains the strongest mode choice structure and has the most sophisticated market segmentation. Although the potential of this modelling process is the greatest, problems deriving from inadequate stated preference data collection made calibration more difficult than it would have seen otherwise. It is also weakened by a subjective projection of total demand, to which the mode diversion models must be applied. In the end, CRA did use the common total demand estimates, as required by the study management.

The TEMS forecasting approach represents perhaps the most comprehensive and flexible model structure, with a high degree of spatial disaggregation and detailed network representation. It also utilizes the total intercity travel market as the base for projection. However, the complexity of the model structure results in cumbersome calibration procedures, with a need for manual adjustment, particularly within the hierarchial structure. Also, the level of consistency in the mixed use of stated and revealed preference data is of some concern.

The SOFRERAIL model package derives from an operations perspective, with a high degree of disaggregation by time of day and O-D pair and the use of a more sophisticated frequency variable. This adds a complexity which is generally unnecessary for medium and long-range forecasting. The mode share model is also inconsistent with standard theory and practice, and seems to produce a high degree of variation in model parameters.

Judgements, at this point, are based on a review of model structure and calibration procedures. It remains to interpret the implications of this initial assessment on forecast results for controlled scenarios, where inputs are held as constant as is possible for all three forecasting models.

3. COMPARISON OF TEST RESULTS

The true tests of model differences comes in the application of the three models to forecasting under the same set of base conditions. While this concept of comparative testing is quite straightforward, its application is not, since each of the three forecasting models has its own peculiar input requirements, making absolutely identical model application unachievable.

The definition of the controlled scenarios, or "test runs" were presented in a memo from IBI dated August 18, 1993. The requirements were established as follows:

1- Forecasts to the year 2005, for the full Quebec-Windsor corridor;

2- 200 km/h and 300 km/h service;

3- HSR fares set at 60 % of specified airfares;

4- total market growth rates constant at pre-specified levels, and

5- fixed operating plan.

As indicated, some differences between the input assumptions of the three models still existed (for example, the assumed access times), due to inherent differences in model requirements. While some checks on the commonality of inputs were conducted, time did not permit a full comparison. However, as much as possible, the test runs should provide a relatively common base for comparative purposes, so that any variations in output are strictly related to differences in model structure and calibration.

In conducting an analysis of the output results from the SOFRERAIL, CRA and TEMS demand forecasting models, there are three general approaches which may be taken. The first is to compare the three sets of ridership estimates from the perspective of a number of dimensions, and the second is to assess the essential model parameters (elasticities, values of time and frequency and modal constants). Thirdly, a number of reality checks may be undertaken, in the form of internal consistency checks, sensitivity tests and comparisons with other similar studies.

For the purpose of this report, emphasis was given to the first type of comparison. In the case of the second type, a full set of consistent parameters were not available from all these forecasters, so this approach was limited in extent. For the third type of comparison, time did not permit reality checks at all, even though this was fully intended.

The comparison of model tests results involved the assessment of four sets of output*: total corridor volumes, individual major O/D pair volumes, diverted and induced trips, and trips by purpose. In the time frame allotted for the comparative analysis, passenger revenue estimates were not available from all consultants, so revenues were not reviewed. Time did also not permit the assessment of trip length frequency distributions, so that no consideration could be given to short and long trip variations.

3.1 Total HSR Trip Volumes

The full set of projections on all three forecasters are presented in Table 2. It is immediately apparent that, not only are the total ridership estimates different, but the basis for the estimates are also quite dissimilar. While the TEMS projections are the lowest of the three (CRA is 4 % higher and SOFRERAIL 42 % higher), the totals for each derive from different sets of intercity pairs. TEMS, in fact, considers a wider set of O-D pairs, with 25 % of the total coming from city pairs that are not even considered by the other two consultants. As a result, even if one takes a common set of major city pairs (7 and 24 city-pair subtotals are given in Table 1), the differences between the low TEMS projections and the other two projections are even more amplified.

The results of the three sets of projections are also provided in Figure 1, in a summary form that is more easily interpreted. It is apparent here that the estimates of diverted trips for TEMS, CRA AND SOFRERAIL are much more similar in value (7.9 m, 8.7 m and 9.4 m, respectively) indicating that the differences in total trips are due primarily to the estimates of induced demands. This point will be considered further elsewhere in the report.

3.2 Volumes for Major O-D Pairs

In order to attempt to understand the differences in total estimates of demand, it is helpful to assess the projections in spatially disaggregate form, by city pair. Figure 2 provides a simple description of the three sets of projections by city pair, so that the degree of disagreement within the corridor becomes readily apparent. For the seven major city pairs, TEMS values are consistently low, while the CRA and SOFRERAIL results alternates from high to intermediate values. For the remaining seventeen city pairs, there are major discrepancies between the three forecasters, most especially in regard to city pair 11 (Kingston-Ottawa), 14 (Montréal-Trois-Rivières), 20 (Kitchener-Montréal), and 23 (Windsor-Kitchener). It is interesting to note as well, that, while in 1992 the highest VIA Rail ridership in the corridor is between Montréal and Toronto, for the projections to the year 2005, it is Montréal/Quebec City for SOFRERAIL and Toronto/Ottawa for TEMS and CRA.

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* For ease of presentation, results for the 300 km/h case only are provided.

TABLE 2
HIGH-SPEED RAIL RIDERSHIP PROJECTIONS - 2005

TEST RUN : 300+ km/h OPTION

O/D Pairs	Sofrerail			CRA			TEMS (Superzone Volumes)		
	Bus.	N-B.	Total	Bus.	N-B.	Total	Bus.	N-B.	Total
Quebec - Trois Rivieres				2,543	5,251	7,794	338	3,709	4,047
* Quebec - Montreal	450,000	1,630,000	2,080,000	433,522	659,807	1,093,329	271,763	341,636	613,399
Quebec - Ottawa	46,000	100,000	146,000	56,543	54,817	111,460	41,602	48,529	90,131
Quebec - Kingston				580	1,923	2,503	n/a	n/a	n/a
Quebec - Toronto	100,000	135,000	235,000	96,283	61,941	158,224	70,484	128,567	199,051
Quebec - Kitchener				5,223	1,034	6,257	n/a	n/a	n/a
Quebec - London				3,325	1,233	4,558	n/a	n/a	n/a
Quebec - Windsor				0	1,507	1,507	n/a	n/a	n/a
Trois Rivieres - Montreal	37,000	393,000	430,000	65,212	255,100	320,312	12,901	32,677	45,578
Trois Rivieres - Ottawa	6,000	64,000	70,000	3,029	7,456	10,485	10,137	38,278	48,465
Trois Rivieres - Kingston				1,564	0	1,564	n/a	n/a	n/a
Trois Rivieres - Toronto	11,000	37,000	48,000	347	6,287	6,634	29,549	86,618	116,167
Trois Rivieres - Kitchener				242	0	242	n/a	n/a	n/a
Trois Rivieres - London				0	0	0	n/a	n/a	n/a
Trois Rivieres - Windsor				0	0	0	n/a	n/a	n/a
* Montreal - Ottawa	398,000	806,000	1,204,000	327,645	753,967	1,081,612	334,353	321,102	655,455
Montreal - Kingston	28,500	140,500	169,000	21,695	84,723	106,418	20,136	19,798	39,934
* Montreal - Toronto	812,000	1,090,000	1,902,000	773,392	616,231	1,389,623	488,262	737,824	1,226,086
Montreal - Kitchener	15,000	32,000	47,000	10,605	18,053	28,658	86,272	196,951	283,223
Montreal - London	12,500	64,500	77,000	18,249	30,933	49,182	7,177	35,632	42,809
Montreal - Windsor				25,696	20,067	45,763	38,550	49,087	87,637
Ottawa - Kingston	193,500	655,500	849,000	74,969	240,442	315,411	51,876	83,558	135,434
* Ottawa - Toronto	759,500	1,063,500	1,823,000	1,285,344	687,017	1,972,361	802,750	490,641	1,293,391
Ottawa - Kitchener	6,500	40,500	47,000	6,406	26,158	32,564	9,286	19,664	28,950
Ottawa - London	26,000	56,000	82,000	46,503	35,991	82,494	39,732	30,047	69,779
Ottawa - Windsor				10,426	23,657	34,083	5,646	41,454	47,100
* Kingston - Toronto	221,000	699,000	920,000	234,632	436,967	671,599	159,680	310,870	470,550
Kingston - Kitchener	14,000	17,000	31,000	4,126	12,609	16,735	0	12,087	12,087
Kingston - London	7,500	22,500	30,000	4,359	19,036	23,395	3,752	18,179	21,931
Kingston - Windsor				2,324	7,054	9,378	15,559	10,947	26,506
Toronto - Kitchener	71,000	408,000	479,000	28,419	239,458	267,877	57,406	352,774	410,180
* Toronto - London	237,000	984,000	1,221,000	382,972	844,473	1,227,445	175,824	371,162	546,986
* Toronto - Windsor	162,000	465,000	627,000	277,410	274,996	552,406	123,872	251,897	375,769
Kitchener - London	97,500	175,500	273,000	3,752	60,239	63,991	17,353	142,252	160,105
Kitchener - Windsor	102,000	215,000	317,000	18,557	30,921	49,478	0	25,418	25,418
London - Windsor	196,000	360,000	556,000	102,765	220,557	323,322	29,154	97,009	126,163
Other Pairs							611,291	1,340,256	2,451,547
Total HSR Trips	4,009,500	9,653,500	13,663,000	4,329,757	5,739,903	10,069,660	3,515,255	6,138,623	9,653,878
Seven Pair (*) Subtotal	3,039,500	6,737,500	9,777,000	3,715,417	4,273,458	7,988,875	2,356,504	2,825,132	5,181,636
24 Common Pair Subtotal	4,009,500	9,653,500	13,663,000	4,277,336	5,678,179	9,955,515	2,843,871	4,193,170	7,037,041

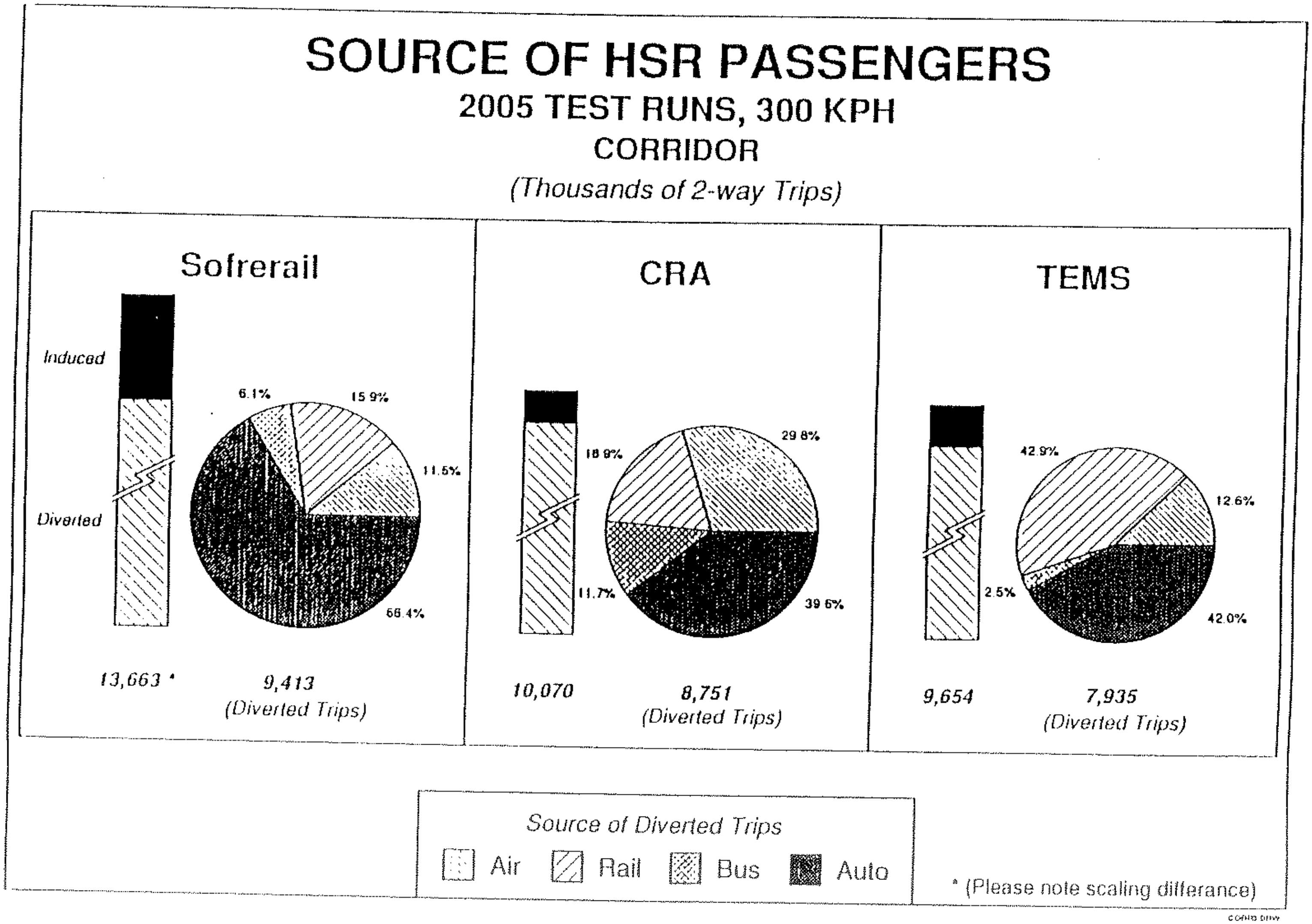
Notes: Non-Business trips include commuters.

Some of the O/D pair volumes from Sofrerail have been slightly adjusted to match the totals.

TEMS values are based on station-to-station forecasts.

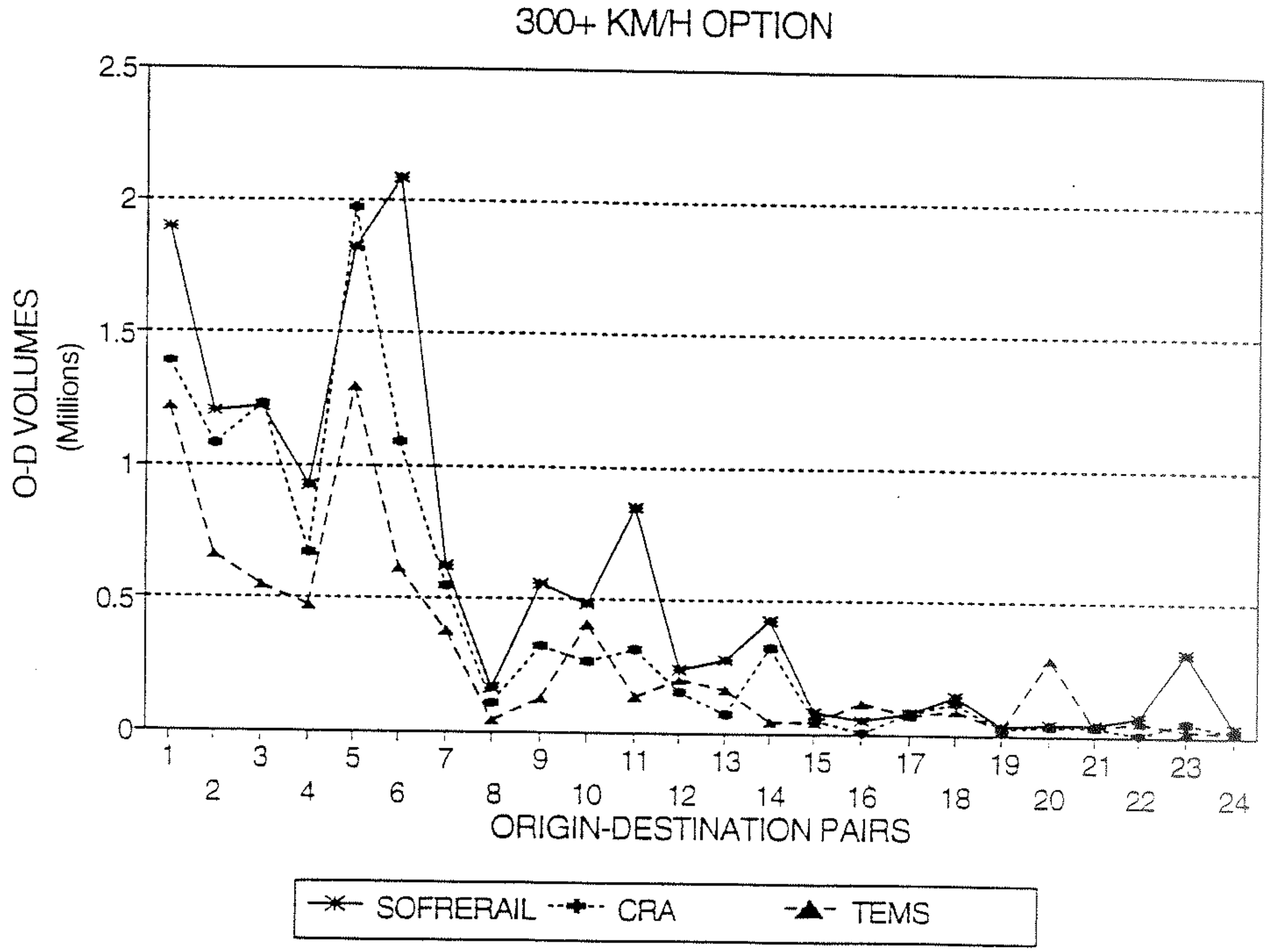
n/a means that the specific volumes are not available. They are included within "other pairs".

FIGURE 1



SOURCE OF HSR PASSENGERS
2005 TEST RUNS, 300 KPH
CORRIDOR
(Thousands of 2-way Trips)
Sofrerail
Induced
Diverted
6.1%
15.9%
11.5%
66.4%
13,663 *
9,413
(Diverted Trips)
CRA
18.9%
29.8%
11.7%
39.6%
10,070
8,751
(Diverted Trips)
TEMS
42.9%
12.6%
2.5%
42.0%
9,654
7,935
(Diverted Trips)
Source of Diverted Trips
Air
Rail
Bus
Auto
* (Please note scaling differance)

FIGURE 2
HIGH-SPEED RAIL RIDERSHIP BY CITY PAIR



Major O-D Pairs

1 - Toronto/Montreal
2 - Ottawa/Montreal
3 - London/Toronto
4 - Toronto/Kingston
5 - Toronto/Ottawa
6 - Montreal/Quebec
7 - Windsor/Toronto

As it was the case in section 3.1, the true differences between the three sets of projections may be seen more easily through the use of bar and pie charts. Figures 3 (Montréal/Toronto), 4 (Toronto/Ottawa), and 5 (Montréal/Quebec City) have been selected as examples. The scale and relative order of magnitude is dramatically different by consultant. It is obvious that this diversity has many other characteristics as well, and these will be considered in the section to follow.

3.3 Diverted and Induced Trips

With the assessment of the magnitude of HSR trips as projected by the three consultants, the next step is to consider the reasons why the estimates are so different, for the same input assumptions. Of particular interest is the source of the travellers, namely, the modes from which existing travellers are diverted, and the number of new travellers (those who would not have travelled at all, if there were no HSR service).

Figures 1,3,4 and 5 summarize both diverted and induced trip estimates, for total corridor movements and for three selected O/D pairs. In general, SOFRERAIL projects high auto diversion, TEMS high conventional rail diversion and CRA high air diversion. (Figure 1).

In the case of the SOFRERAIL model, there can be little doubt that its results are affected by the independence from irrelevant alternatives (IIA) property of any multimodal share model. The IIA property is one in which travellers on the HSR mode are drawn from the other modes in direct proportion to the share of trips made on the existing modes. Since auto users make up 85 % of existing intercity trips, diversion takes place accordingly, under the IIA condition. This occurs, quite simply, because the probability of an individual choosing a particular mode is a function only of its utility relative to the utility of all other modes (ie - it is unaffected by the introduction of new alternatives of modes; they are irrelevant).

For the SOFRERAIL model, it is also likely that the high auto diversions (66 %) are due to the fact that the model was calibrated using only pre-screened auto trips from the revealed preference data base (ie - captive auto trips were eliminated). Auto trips which were not "likely" to be diverted were removed from the data file. This is an example where the calibration procedure influences the model results; the IIA property is a case where the model structure affects the model results, even when input assumptions are the same.

It should also be noted that the TEMS model incorporated assumptions regarding an increase in conventional rail service, that was not in accord with the other two forecasters. This no doubt explains much of the diversion (43 %) from conventional rail to high-speed rail.

FIGURE 3

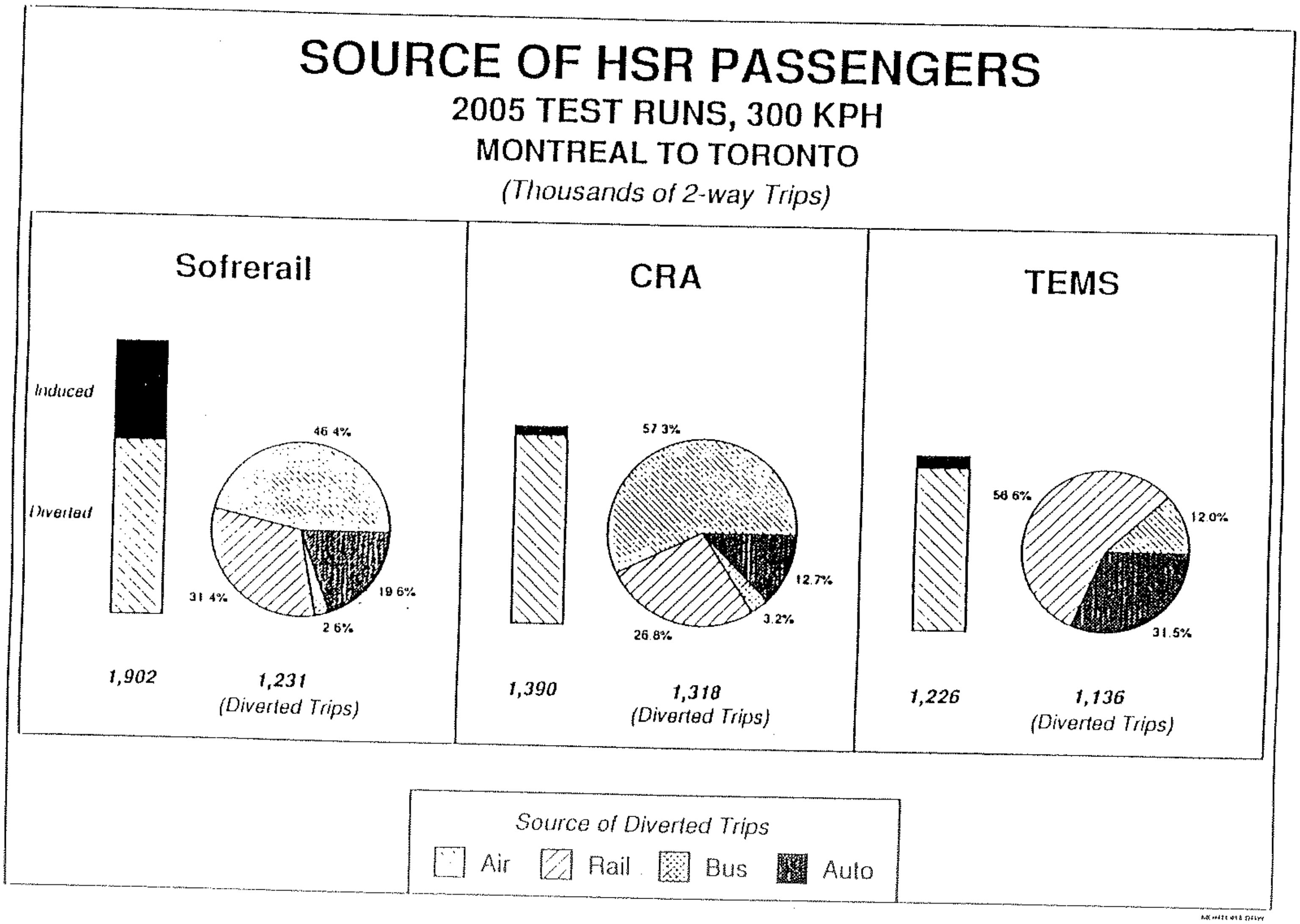

SOURCE OF HSR PASSENGERS
2005 TEST RUNS, 300 KPH
MONTREAL TO TORONTO
(Thousands of 2-way Trips)
Sofrerail
Induced
Diverted
46.4%
31.4%
2.6%
19.6%
1,902
1,231
(Diverted Trips)
CRA
57.3%
26.8%
3.2%
12.7%
1,390
1,318
(Diverted Trips)
TEMS
56.6%
12.0%
31.5%
1,226
1,136
(Diverted Trips)
Source of Diverted Trips
Air
Rail
Bus
Auto

FIGURE 4

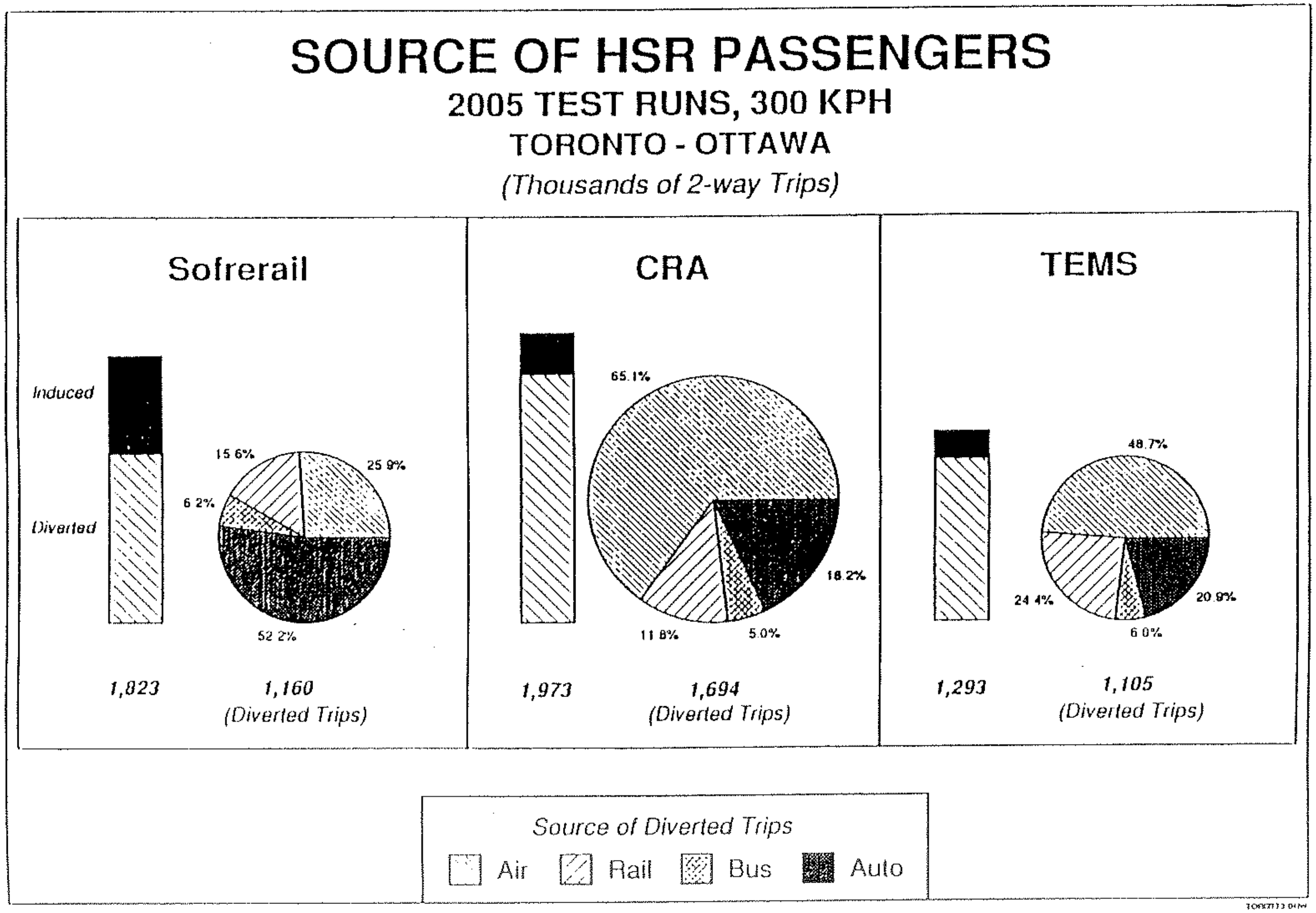
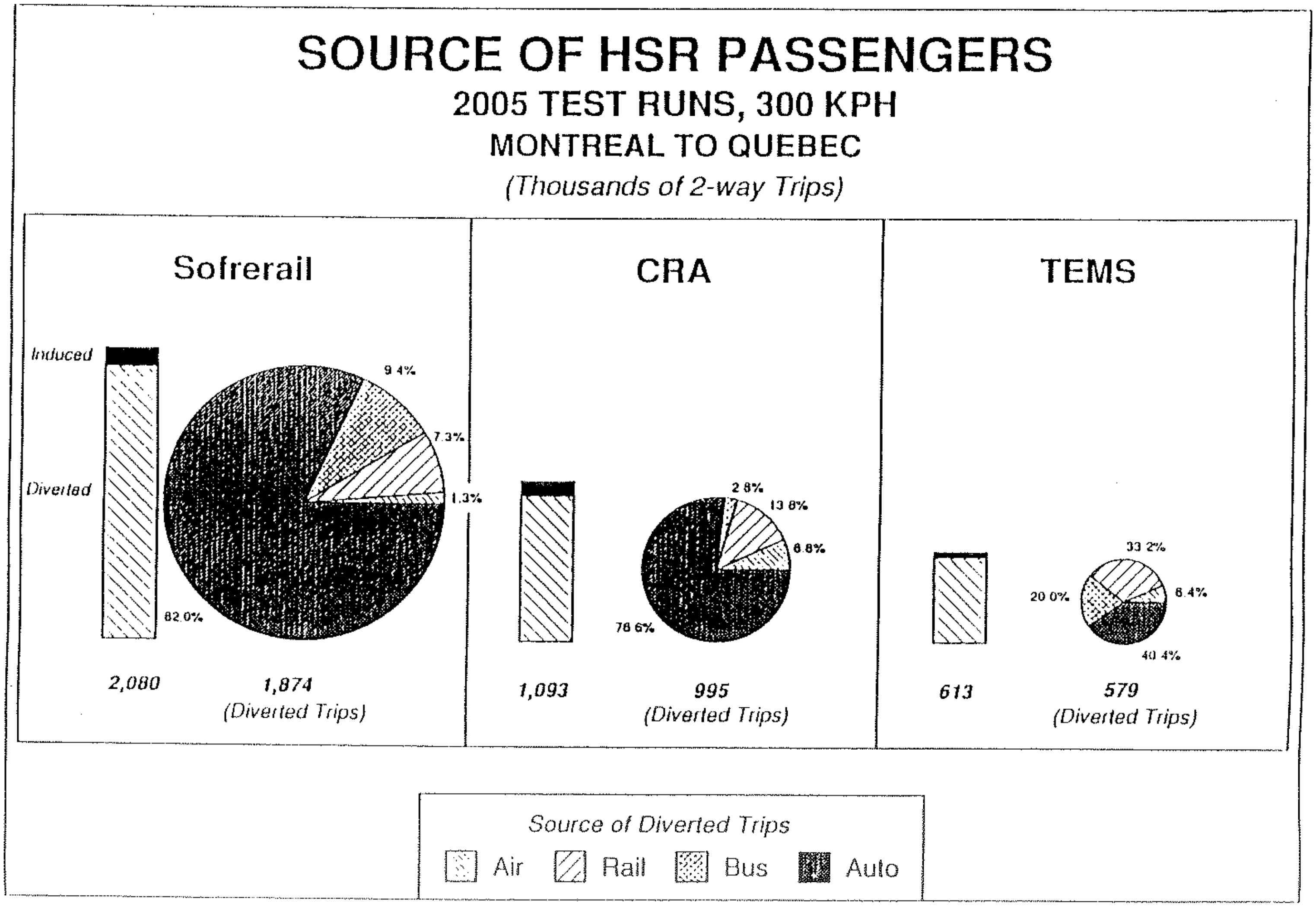

SOURCE OF HSR PASSENGERS
2005 TEST RUNS, 300 KPH
TORONTO - OTTAWA
(Thousands of 2-way Trips)
Sofrerail
Induced
Diverted
15.6%
25.9%
6.2%
52.2%
1,823
1,160
(Diverted Trips)
CRA
65.1%
18.2%
11.8%
5.0%
1,973
1,694
(Diverted Trips)
TEMS
48.7%
24.4%
20.9%
6.0%
1,293
1,105
(Diverted Trips)
Source of Diverted Trips
Air
Rail
Bus
Auto

FIGURE 5


SOURCE OF HSR PASSENGERS
2005 TEST RUNS, 300 KPH
MONTREAL TO QUEBEC
(Thousands of 2-way Trips)
Sofrerail
Induced
Diverted
9.4%
7.3%
1.3%
82.0%
2,080
1,874
(Diverted Trips)
CRA
2.8%
13.8%
6.8%
76.6%
1,093
995
(Diverted Trips)
TEMS
33.2%
20.0%
6.4%
40.4%
613
579
(Diverted Trips)
Source of Diverted Trips
Air
Rail
Bus
Auto

Finally, it is worth nothing as well, that Figures 3, 4 and 5 show that there is some agreement on trip diversions for selected O/D pairs. For example, for the Montréal/Toronto corridor, both SOFRERAIL and CRA predict significant air diversion. For the Toronto/Ottawa corridor, high air diversion are predicted by CRA and TEMS, and for the Montréal/Quebec City corridor, all three consultants are in agreement on the extent (but not absolute magnitude) of auto diversions.

For the induced travel market, the SOFRERAIL results (at 31 % of the market) are considerably different than those of CRA (18 %) and TEMS (13 %). Once more, the SOFRERAIL estimates are consistently higher, for most or all city pairs, so the differences are quite obviously a function of alternative induced demand model formulations. The TEMS results, in fact, exhibited a number of anomalies which could not be explained.

3.4 Trip Purpose

Another travel demand segmentation that is most important in understanding model structure and forecasting ability is that related to trip purpose (in this case, business and non-business travel). Table 3 summarizes the HSR market share by the two trip purposes, for a selected set of O-D pairs. Once again the differences in model and calibration procedures result in differing output for the three models. Generally, the SOFRERAIL model estimates a higher market share for non-business travellers that do the CRA and TEMS models. For the business traveller, the CRA model quite consistently estimates the highest HSR share, and TEMS the lowest. These differences are difficult to explain, but are obviously a function of the model characteristics themselves. It is expected that these differences would be apparent in a comparison of elasticities by trip purpose.

Figure 6 provides a visual representation of HSR market share by trip purpose, for the Montréal/Toronto corridor. In this particular case, the SOFRERAIL and TEMS models project higher market penetration than CRA for the non-business market, while CRA has the highest market penetration for the business market.

3.5 Model Parameters

Conceptually, much can be learned about a transport demand model from the values of its elasticities of demand, values of time and frequency and modal constants. In particular, comparison of these parameters with both empirical evidence and other model applications can be most instructive. Unfortunately, in this case, time and availability did not permit adequate comparisons to be conducted.

TABLE 3
HIGH-SPEED MARKET SHARE BY TRIP PURPOSE FOR SELECTED O-D PAIRS

TEST RUNS, 300 KPH

	SOFREFAIL	CRA	TEMS
Corridor			
Total	21%	16%	7%
Bus	23%	25%	12%
Non-bus	20%	13%	6%
Montréal-Toronto			
Total	42%	30%	30%
Bus	36%	33%	23%
Non-bus	49%	26%	38%
Toronto-Ottawa			
Total	43%	44%	31%
Bus	40%	64%	46%
Non-bus	46%	28%	20%
Montréal-Ottawa			
Total	20%	18%	10%
Bus	28%	23%	23%
Non-bus	17%	16%	6%
Montréal-Québec			
Total	23%	12%	6%
Bus	19%	17%	10%
Non-bus	25%	10%	5%
Toronto-Kingston			
Total	29%	22%	14%
Bus	33%	36%	23%
Non-bus	29%	18%	12%
Toronto-London			
Total	20%	20%	8%
Bus	15%	23%	10%
Non-bus	21%	18%	8%
Toronto-Windsor			
Total	32%	27%	20%
Bus	38%	48%	26%
Non-bus	30%	19%	18%

Generally speaking, it would appear that the implied values of time and demand elasticities relative to time, frequency and cost are within reasonable bounds for the CRA and TEMS model formulations. Specific conclusions are difficult, however, since CRA modified calibration procedures to achieve reasonable values of time and frequency, and TEMS developed a modified hierarchial structure for the mode choice model, but new model parameter values were not available for assessment.

For the SOFRERAIL model, on the other hand, elasticities of time and frequency were excessively high, and well beyond comparative measures from other studies. This no doubt reflects a different empirical base, but of concern as well is the high degree of variability within the model itself. As calibration is done on a city pair by city pair basis, an assessment was made of the basic model parameters for each OD pair. Il was noted that many of the parameters exhibited extreme and unexpected variations, especially for business travel. Of particular concern were the modal constants, given their importance within the mode choice model. It should be remembered that the major conclusion of the Air Canada/CP Rail study was that the mode constants had the most significant influence in the sensitivity tests. Yet the SOFRERAIL model has to assume rather than calculate the HSR modal constant, and does so by taking the minimum value from the calculated mode constants for the exiting modes.

In summary, it is not possible to be conclusive in regard of model parameters. If more information from the individual modellers had been available and time had permitted, a more in-depth analysis could have been conducted. As it is, any findings are quite cursory.

4. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the task of technical assessment of the three passenger demand models can be said to be only partially successful. In spite of all of the efforts to ensure direct comparability in the test runs, all things were not equal. The most instructive element of the technical comparison was, without doubt, the review of model structure and calibration procedures. This is where most of the significant differences between the three demand models became apparent (see section 2.3) and it is obviously these differences which produced the wide variation in results of the test runs. As noted, these differences were not just in total patronage estimates, but were apparent in the composition of the demand, in terms of both diversions and new or induced travellers, by trip purpose.

Generally, it is not possible to directly link the inherent model characteristics with the nature of the demand estimates in the test runs, due to the complexity of the estimation procedures. Further analyses of the model parameters would have been of assistance, as indicated in section 3.5. Some relationships, however, are quite obvious, such as the existence of the IIA problem in the SOFRERAIL model and the high auto diversions, or the hierarchal structure and incompatible application of data sets and the difficulty of calibration in the TEMS model.

In essence then, the conclusions on model structure as described in section 2.3 of the report form the basis for the final recommendation of the technical review team. To the extent that these conclusions are supported by the subsequent forecasts. For the test runs, this strengthens the recommendation for model selection.

It is recommended that the Quebec/Ontario High-Speed Rail Project select the demand estimation model developed and calibrated by the CRA team as the basis for the remaining analyses in the study. While the results from the TEMS and SOFRERAIL models may provide considerable guidance in the development of sensitivity tests and confidence limits, technical consistency requires that all further dependency be placed on the single set of forecast procedures.